

Space Mechanisms Lessons Learned and Accelerated Testing Studies

A number of mechanism (mechanical moving component) failures and anomalies have recently occurred on satellites. In addition, more demanding operating and life requirements have caused mechanism failures or anomalies to occur even before some satellites were launched (e.g., during the qualification testing of GOES-NEXT, CERES, and the Space Station Freedom Beta Joint Gimbal). For these reasons, it is imperative to determine which mechanisms worked in the past and which have failed so that the best selection of mechanically moving components can be made for future satellites. It is also important to know where the problem areas are so that timely decisions can be made on the initiation of research to develop future needed technology.

To chronicle the life and performance characteristics of mechanisms operating in a space environment, a Space Mechanisms Lessons Learned Study was conducted. The work was conducted by the NASA Lewis Research Center and by Mechanical Technologies Inc. (MTI) under contract NAS3-27086. The expectation of the study was to capture and retrieve information relating to the life and performance of mechanisms operating in the space environment to determine what components had operated successfully and what components had produced anomalies. The table lists some mechanism anomalies found in spacecraft that are discussed in two publications on this subject (refs. 1 and 2).

MECHANISM ANOMALIES IN SPACECRAFT

System	Conditions	Problem	Impact
Momentum wheel spin bearings	3600-rpm, grease-packed bearings; room temperature to 100 °F	Torque and temperature anomalies	Single-point mission failure; possible indication of failure
Sensor support bearing	Preloaded ball bearings oscillatory motion	Failure in test	>\$500,000 testing
Sensor launch clamp	Clamp located inside thermal blanketed craft	Seizure on launch pad	Single-point failure prohibited launch or mission failure
Harmonic drives	Very low speed; temperature <150 °F; fluorocarbon lubricant; boundary condition	Excessive wear; lube failure in test	Failure will degrade mission or possible mission failure; changed lubricant
Slip rings; brush contacts	MoS ₂ /Ag/C brushes on Ag rings; numerous recurrences	Excessive electrical noise due to moisture and corrosion	Inability to point antennas; reduced mission objective

Potentiometer for ATP control	Low temperature; light load fluid lubricant	Electrical noise lube thickening open circuit	Loss of pointing reduced mission ~\$500,000 testing
Control moment gyroscope	Oil injection on bearing land	Bearing failure lube design wrong	Premature mission failure
Control moment gyroscope	Very high torque for slewing	Bearing failure	Loss of mission; >\$1 million test and anneal
Momentum wheel	Grease lubricated	Torque and temperature anomalies	Possible mission failure
Propellant pump gearbox	High speed	Contractor switching lubricants	Possible launch failure with new lube
Slip rings; brush contacts	MoS ₂ /Ag/C brushes on Ag rings	Excessive noise due to oxidation of MoS ₂	Rework brushes and rings; delivery delay
Gear mechanism	High loads; fluorocarbon grease; boundary conditions	Lube degradation	System failure
Synchronous motor assembly	Mineral oil grease-packed bearings	Motor failure due to increased bearing drag	Failure would degrade mission
Momentum wheel spin bearings	High speed; mineral oil grease	Possible lubricant degradation in testing	Single-point mission failure
Inertial guidance synchronous motor bearing	High speed; mineral oil grease	Possible chemical reaction between grease and iron surface during storage	Guidance failure
Harmonic drive	Low-temperature operation; fluorocarbon grease	Low-temperature viscosity of grease causes excessive torque	Failure will degrade mission
Momentum wheel; active lubrication system	High-speed; long-life requirement	Inability to deliver adequate lubricant quantity	System will not meet lifetime requirement
SADM	Large launch loads on MoS ₂ - lubricated bearings	Test of static loads	Possible single-point failure; passed test
Gimbal bearings on test; telescope	Low-temperature; dry (MoS ₂) lubricant	Tested in air friction increase	Modified specification to do inert gas test; passed
Spin bearing	Large diameter, thin cross section bearing	Humidity-induced dimensional instability of cotton-phenolic retainer	Possible target acquisition failure; changed to metal ball separator

Gas bearing; gyroscope	Alumina surfaces; stearate lubricant	Erratic friction on startup; uneven lube during test	Reliability problem for flight units; major rework if failure
Foil bearings for turbomachinery	High-strength alloy; CF _x -polyamide lubricant; temperature extremes	High friction startup after standing	Potential system failure; inability to start turbine

The goal of building longer-life unmanned satellites and space probes has created a demand for meaningful accelerated test methods to simulate long-term service in space. This is particularly true for tribological components used in space--such as bearings, seals, and gears. In addition, there is an urgent need for lightweight, low-torque, durable mechanisms that can operate efficiently in a hard vacuum environment.

In response to this need, a study was conducted by Lewis and MTI (under contract NAS3-27086) to determine if any mechanisms (which operate in the space environment) would benefit from accelerated testing techniques (ref. 3). The study investigated the current types of accelerated testing techniques, their shortfalls, and the need to develop new techniques. An accelerated testing technology "roadmap" was developed for assessing the life and reliability of spacecraft mechanical systems by accelerated testing methods. The "roadmap" suggested that system components testing, analytical modeling, computer codes, and computer smart systems could be integrated into a methodology that could be used to predict or verify the life and reliability of a mechanical system. The study team suggested that a space mechanism mechanical system be tested to demonstrate that the methods developed could adequately predict the life and/or performance of a mechanism. Included in the "roadmap" are the experimental equipment needed, the test procedures, the time guidelines, and cost analysis.

References

1. Shapiro, W., et al.: Space Mechanisms Lessons Learned Study, Volume I--Summary. NASA TM-107046, 1995.
2. Shapiro, W., et al.: Space Mechanisms Lessons Learned Study, Volume II--Literature Review. NASA TM-107047, 1995.
3. Murray, S.F.; and Heshmat, H.: Accelerated Testing of Space Mechanisms. NASA CR-198437, 1995.

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